

IN THE UNITED STATES DISTRICT COURT  
FOR THE DISTRICT OF DELAWARE

CIF LICENSING, LLC, d/b/a  
GE LICENSING,

Plaintiff,

AGERE SYSTEMS INC.,

Defendant.

C.A. No. 07-170-JJF

**DEFENDANT AGERE SYSTEM INC.'S  
RESPONSIVE CLAIM CONSTRUCTION BRIEF**

YOUNG CONAWAY STARGATT & TAYLOR LLP  
John W. Shaw (No. 3362)  
jshaw@ycst.com  
Jeffrey T. Castellano (No. 4837)  
jcastellano@ycst.com  
The Brandywine Building  
1000 West Street, 17th Floor  
Wilmington, DE 19899-0391  
302-571-6600

-and-

TOWNSEND AND TOWNSEND AND CREW LLP  
David E. Sipiora  
Ian L. Saffer  
Chad E. King  
1200 Seventeenth Street, Suite 2700  
Denver, Colorado 80202-5827  
303-571-4000

*Attorneys for Defendant Agere Systems Inc.*

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Pursuant to the Court's Order of September 19, 2007, D.I. 32, and in response to CIF Licensing, LLC, d/b/a GE Licensing's Opening Claim Construction Brief ("GE's Opening Brief"), D.I. 89, Defendant Agere Systems Inc. ("Agere"), submits this Responsive Claim Construction Brief.

## **I. CLAIM CONSTRUCTION LAW**

Throughout GE's Opening Brief, CIF Licensing, LLC, d/b/a GE Licensing ("GE") relies heavily on extrinsic evidence in the form of publications and declarations from its own expert. In contrast, in Defendant Agere System Inc.'s Opening Claim Construction Brief ("Agere's Opening Brief"), D.I. 87, Agere construes the disputed terms relying only on intrinsic evidence. This difference between the Parties' analysis is substantial and meaningful. Under established and binding Federal Circuit law, this Court should give greater weight to intrinsic evidence offered by Agere as against extrinsic evidence offered by GE.

In construing patent claims, the Federal Circuit has made abundantly clear its position regarding the relative value of intrinsic evidence and extrinsic evidence. Regarding intrinsic evidence in the form of a patent's specification, the Federal Circuit has stated, "the specification 'is always highly relevant to the claim construction analysis. Usually, it is dispositive; it is the single best guide to the meaning of a disputed term.'"<sup>1</sup> The Federal Circuit has held that a patent's specification should be the primary basis for construing claims.<sup>2</sup> This close relationship between the specification and the meaning of claim terms arises from a mandate by the Patent

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<sup>1</sup> *Phillips v. AWH Corp.*, 415 F.3d 1303, 1315 (Fed. Cir. 2005) (citing *Vitronics Corp. v. Conceptronic, Inc.*, 90 F.3d 1576, 1582 (Fed. Cir. 1996)).

<sup>2</sup> *Standard Oil Co. v. Am. Cyanamid Co.*, 774 F.2d 448, 452 (Fed. Cir. 1985).

Act that the specification describe in detail the claimed invention.<sup>3</sup> Thus, it is appropriate for the Court to rely heavily on intrinsic evidence from the specification when construing claim terms.<sup>4</sup>

In stark contrast, the Federal Circuit has warned about using extrinsic evidence in claim construction. Regarding extrinsic evidence in the form of expert testimony, the Federal Circuit has stated, "conclusory, unsupported assertions by experts as to the definition of a claim term are not useful to a court."<sup>5</sup> Further, an expert's opinions on claim construction may show bias of the offering party, and this bias may be exacerbated by lack of cross-examination.<sup>6</sup> The Federal Circuit has also recognized the problems stemming from the "virtually unbounded universe of potential extrinsic evidence."<sup>7</sup> Within this "unbounded universe," a party will naturally choose only that evidence that supports its position and not bring other contrary evidence to the court's attention.<sup>8</sup> "In sum, extrinsic evidence may be useful to the court, but it is unlikely to result in a reliable interpretation of patent claim scope unless considered in the context of the intrinsic evidence."<sup>9</sup>

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<sup>3</sup> *Phillips*, 415 F.3d at 1316.

<sup>4</sup> *Id.* at 1317.

<sup>5</sup> *Id.* at 1318.

<sup>6</sup> *Id.*

<sup>7</sup> *Id.*

<sup>8</sup> *Id.*

<sup>9</sup> *Id.* at 1319.

## II. CLAIM TERMS – U.S. PATENT NO. 5,048,054 (THE "'054 PATENT")

### A. "Receiver" and "Line probing processor"

Agere's Proposed Construction (Receiver)	GE's Proposed Construction (Receiver)
<i>a hardware device for accepting signals from a remote device</i>	Plain Meaning ( <i>any structure capable of receiving an electrical signal</i> )

Agere's Proposed Construction (Line Probing Processor)	GE's Proposed Construction (Receiver)
<i>a hardware component that processes a line probing signal</i>	<i>a structure that processes a line probing signal</i>

GE's Opening Brief offers little to support the adoption of GE's proposed construction of the terms "receiver" and "line probing processor" over Agere's construction.<sup>10</sup> In its Opening Brief, GE argues that the Court should adopt the "plain meaning" of the term "receiver," but then postulates that the term "receiver" has multiple meanings even within the four corners of the '054 Patent.<sup>11</sup> This position makes no sense. In reality, by conceding that the '054 Patent is ambiguous in relation to the meaning of the term "receiver," GE contradicts the notion that the term should be ascribed its "plain" meaning. Under GE's proposed construction, the term "receiver" would almost certainly render any claim containing that term invalid due to indefiniteness under 35 U.S.C. § 112, ¶ 2 and for failure to meet the enablement requirement of

<sup>10</sup> It appears that the only dispute between GE and Agere with respect to the term "line probing processor" is whether that term should be construed to mean a discrete hardware device or some amorphous "structure." Cf. GE's Opening Brief, at 17. In this respect, the dispute over the parties' respective constructions of the term "line probing processor" mirrors that over the term "receiver." Moreover, as discussed *infra*, GE appears to ask the Court to conflate the "line probing processor" with the "receiver," despite the fact that these are two separate claim elements. Accordingly, this brief discusses both claim terms together.

<sup>11</sup> See GE's Opening Brief, at 14 ("There is no specific description [in the '054 Patent] of receiver, and specific embodiments are shown where a 'receiver' is referred to as both a component of a modem . . . or as the modem itself . . .").

§ 112, ¶ 1, merely because one skilled in the art would have no idea, from the specification of the '054 Patent, which "plain meaning" of the term "receiver" is used in the claims. As such, GE's proposal for construing "receiver" should be rejected as insupportable.

1. GE's proposed construction of "receiver" merely introduces ambiguity.

GE's "plain meaning" actually introduces additional confusion into the term "receiver." GE proposes that the "plain meaning" of the term receiver must include a "structure," a term GE then explains must include "a computing device programmed with software to perform a function."<sup>12</sup> Likewise, GE proposes that a line probing processor includes a similar "structure."<sup>13</sup> GE fails to identify intrinsic support in the '054 Patent GE for such a definition of "structure." Rather, GE appears to be creating this "plain meaning" from whole cloth.

In contrast, Agere's proposed definition of the term "receiver" (a hardware device for accepting signals from a remote device) provides appropriate guidance to the fact finder on the meaning of the term. Moreover, Agere's proposed construction finds support in the intrinsic evidence of the '054 Patent. First, GE apparently does not dispute that the function of the receiver in claim 1 is to accept signals from a remote device.<sup>14</sup> Second, while GE does dispute that the term "receiver" should be construed to mean a hardware device, GE provides no persuasive reasons to conclude that the intrinsic evidence of the '054 Patent supports a broader

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<sup>12</sup> *Id.* at 14 & n. 21.

<sup>13</sup> *Id.* at 17.

<sup>14</sup> GE does quibble with the term "accept a signal from a remote device" in Agere's proposed construction, apparently preferring instead the term "receiv[e] an electrical signal." GE's Opening Brief, at 14. Other than the circularity of the term "receive," there appears to be little difference between the parties' respective formulations, unless GE plans to contend that a modem receiver can receive signals from somewhere other than a remote device, functionality which is both irrelevant to the issues in this case and unsupported by any evidence whatsoever.

interpretation. GE appears even to assert that the claimed "receiver" and "line probing processor" might in fact be the same device,<sup>15</sup> although even a cursory reading of the claims of the patent contradict such a construction.

2. The intrinsic evidence in the '054 Patent fails to support GE's argument.

To the extent that GE takes the position that a receiver and a line probing processor might be the same device, such an interpretation of the claims finds no support in the intrinsic evidence of the '054 Patent. GE implies that there are many embodiments disclosed in the '054 Patent, and that Figure 1 illustrates only one such embodiment. This is simply not correct; Figure 1 provides the only illustration of any embodiment of a modem, and all of the figures (and accompanying description) in the '054 Patent are labeled a "DESCRIPTION OF THE PREFERRED EMBODIMENT." There is simply no support in the '054 Patent for the proposition that, while Figure 1 illustrates a modem having a separate receiver and line probing processor devices, other, undisclosed embodiments might combine those devices.

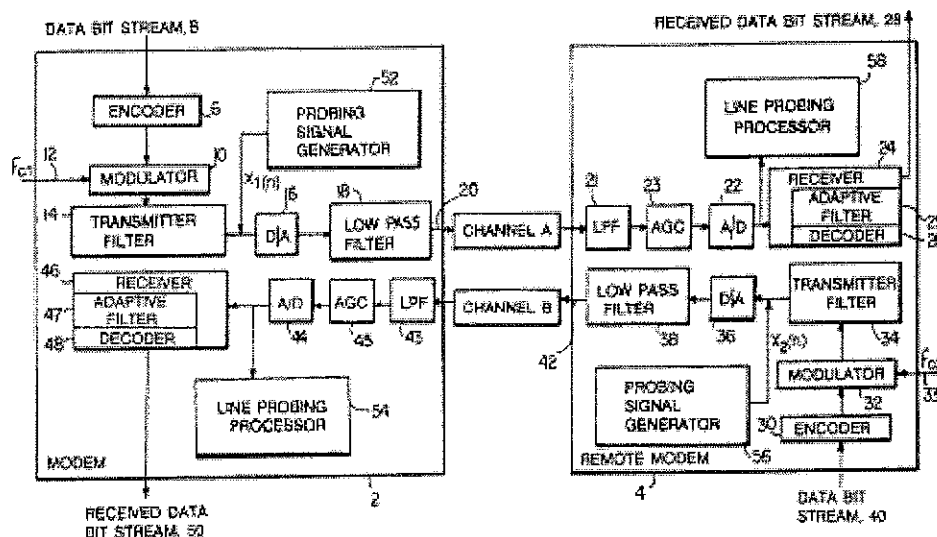
Hence, notwithstanding GE's speculation about a supposed plethora of embodiments disclosed by the '054 Patent, only one embodiment of a modem device is illustrated by the figures and described in the specification of the '054 Patent: the embodiment illustrated on Figure 1 of the '054 Patent (reprinted below for the Court's convenience). Figure 1 clearly depicts a modem 2, which includes several devices, including in particular a receiver 46 and a line probing processor 54.<sup>16</sup> The specification (by reference to remote modem 4, which, as

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<sup>15</sup> See GE's Opening Brief, at 15 n. 22.

<sup>16</sup> Agere's Opening Brief referenced the remote modem 4 of Figure 1, because that modem is described with respect to the receiving functions that are claimed in the asserted claims of the '054 Patent. Because GE's Opening Brief refers to the local modem 2 of Figure 1 instead, this Response Brief also refers to the local modem 2 of the same Figure. As noted in Agere's

noted, is disclosed as being identical to modem 2) clearly indicates that these devices are separate devices, as illustrated by Figure 1: "[T]he received signal passes through a lowpass filter 21, an automatic gain control (AGC) circuit 23, an analog-to-digital (A/D) converter 22 and then a receiver 24, which includes an adaptive filter 25 followed by a decoder 26."<sup>17</sup> The only reasonable inference from the intrinsic evidence is that the modem 2 is made up of several discrete hardware components.



**Figure 1 – U.S. Patent No. 5,048,054**

In contravention of this clear intrinsic evidence, GE attempts to argue that the receiver and the line probing processor of the '054 Patent should not be considered "physically separate hardware devices" (as opposed to found [sic] in a programmable, multifunction general processor

Footnote continued from previous page

Opening Brief, there is no material distinction between the local modem 2 and the remote modem 4 illustrated by Figure 1.

<sup>17</sup> '054 Patent, col. 4, lines 39-43.

or digital signal processor)."<sup>18</sup> GE even goes so far as to argue that the '054 Patent lacks intrinsic evidence for construing the receiver and line probing processor as separate devices.<sup>19</sup> To the contrary, Figure 1, on its face, establishes that, in the only illustrated embodiment of a modem according to the alleged invention of the '054 Patent, the receiver and the line probing processor are clearly depicted as separate devices. As noted above, this illustration, and the accompanying description in the '054 Patent's specification, each comport with the asserted claims, all of which recite a receiver and a line probing processor as separate devices. In fact, nothing in the specification or the prosecution history of the '054 Patent provides any support for GE's position that the receiver and the line probing processor might be implemented as a single device -- *e.g.*, a digital signal processor ("DSP") or computer's central processing unit ("CPU"), such as a Pentium chip or the like.

Indeed, GE's attempt to support its proposed construction through intrinsic evidence illustrates the infirmity of GE's position. Presumably by reference to Figure 1 of the '054 Patent, GE argues that "[t]hough the receiver 46 is depicted as a separate block from the adaptive filter 47 and decoder 48, in the specification, the adaptive filter 47 and decoder 48 are described as being part of the receiver 46. Likewise, claims 8, 18, and 63 say that the 'receiver further comprises . . . ' an 'adaptive filter.'"<sup>20</sup> Rather than supporting GE's position, however, this argument contradicts it. A review of Figure 1 reveals that, in fact, the adaptive filter 47 and the

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<sup>18</sup> GE's Opening Brief, at 15 n. 22.

<sup>19</sup> *See id.*

<sup>20</sup> GE's Opening Brief, at 15 n. 22 (citations omitted).

decoder 48, unlike the line probing processor 54, are shown as being integrated within the receiver 46.

Specifically, as illustrated by Figure 1, the receiver 46 is a large box, with the adaptive filter 47 and the decoder 48 depicted as smaller boxes residing inside the receiver 46. This illustration comports with the remainder of the '054 Patent, which (as GE points out) consistently describes (and even claims) the adaptive filter and the decoder as being part of the receiver.<sup>21</sup> Clearly, the applicant for the '054 Patent contemplated that the receiver would include both the adaptive filter and the decoder.

By contrast, Figure 1, the specification, and the claims of the '054 Patent are consistent in that they never once even imply that the line probing processor might be combined with (or incorporated within) the receiver, either as a combined hardware device or some combination of software running on a DSP or a CPU. Figure 1 indisputably illustrates the line probing processor 54 as being separate from the receiver 46. Similarly, unlike the adaptive filter, the line probing processor is never claimed as part of a receiver. (Conversely, neither the decoder nor the adaptive filter is ever described or claimed in the '054 Patent as being separate from the receiver.) Hence, GE's example of the decoder and adaptive filter shows only that, had the applicant for the '054 Patent contemplated the receiver and line probing processor being combined in any way, he would have disclosed such an arrangement (since he did so with the decoder and adaptive filter). But the applicant did not provide any such disclosure, and the only reasonable inference is that the applicant for the '054 Patent had not conceived of any embodiment in which the receiver and line probing processor were combined.

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<sup>21</sup> See, e.g., '054 Patent, claim 8.

3. GE's purported extrinsic evidence fails to support GE's position.

Failing to find any support in the intrinsic evidence for the position that receiver means, apparently, whatever GE wants it to mean, GE relies primarily on extrinsic evidence, in the form of a declaration from GE's expert, Dr. Harry V. Bims. In his declaration, Dr. Bims asserts, "a person of ordinary skill in the art at the time of the '054 Patent would understand that . . . a receiver in modem 2 of Figure 1 includes low pass filter (LPF) block 43, automatic gain control (AGC) block 45, analog-to-digital (A/D) converter block 44, receiver block 46, and line probing processor block 54."<sup>22</sup> Irrespective of whether Dr. Bims is correct in his unsupported assertion about the understanding of one skilled in the art, this supposed understanding is flatly contradicted by the claims, specification, and figures of the '054 Patent, none of which refer to any of these devices as being part of the receiver. (Indeed, Dr. Bims's description of a "receiver," which appears quite similar to what the '054 Patent describes as a "modem," is internally inconsistent, since Dr. Bims's "receiver" includes the receiver 46 illustrated by Figure 1.)

The lone item of intrinsic evidence that might support Dr. Bims's assertion is the bare labels "transmitter" and "receiver" in Figure 2 of the '054 Patent. These labels are belied, however, by the description of Figure 2 in the specification, which substitutes the terms "local

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<sup>22</sup> Declaration of Dr. Harry V. Bims ("Bims Decl."), D.I. 92, at 6, ¶ 27. Dr. Bims purports to support this assertion by citation to a book describing, in an unknown context, a receiver as a device that includes several "operations," but notably omits mention of any of the "blocks" Dr. Bims considers to be part of a receiver. *Id.* at 7, ¶ 28. While it is true that two of the operations mentioned by this book include decoding and filtering, those two operations, however, would appear to correspond to the adaptive filter 47 and decoder 48, which as noted above, the '054 Patent teaches are a part of the receiver 46. Hence, while the book cited by Dr. Bims appears to agree, to some degree, with the disclosure of the '054 Patent, it does not support Dr. Bims's assertion.

modem" and "remote modem," respectively, for the labels "transmitter" and "receiver."<sup>23</sup>

Moreover, these labels in no way correlate to any of the structural features illustrated by Figure

1. The only reasonable inference from this inconsistency is that the labels on Figure 2 represent either an imprecise shorthand or an inadvertent mistake. In either case, these labels, standing alone, are in no way determinative of what the applicant means by the terms "transmitter" and "receiver," given their inconsistency with the remainder of the intrinsic evidence.

4. The scope of the claims properly must be limited to the scope of the applicant's disclosed invention.

GE argues that Agere's construction is an attempt to impose on the term "receiver" limitations from the specification. To the contrary, Agere's proposed construction is the only construction that finds any support in the specification. The Federal Circuit has held that a claim term properly may be limited to the scope of the invention, as defined by the specification, when the patentee attempts to seek a construction that is broader than that disclosed by the patent's specification.<sup>24</sup> In fact, construing a claim term more broadly than the support of the patent's disclosure exposes that claim to the risk of invalidity under 35 U.S.C. § 112, ¶ 1, and the

<sup>23</sup> See '054 Patent, col.10, lines 10-52.

<sup>24</sup> See, e.g., *Laitram Corp. v. Morehouse Industries, Inc.*, 143 F.3d 1456, 1462-63 (Fed. Cir. 1998) ("[W]e do not agree that the court's observation that the patents' written description discloses only flat driving surfaces erroneously reads that structure into the claims. . . . While claims are not necessarily limited by the written description, it is relevant that nothing in the written description suggests that the driving surfaces can be anything but flat."); accord *Phillips v. AWH Corp.*, 415 F.3d 1303, 1316-17 (Fed. Cir. 2005) (en banc), cert. denied, 126 S. Ct. 1332 (2006), ("Indeed, the rules of the PTO require that application claims must 'conform to the invention as set forth in the remainder of the specification and the terms and phrases used in the claims must find clear support or antecedent basis in the description so that the meaning of the terms in the claims may be ascertainable by reference to the description.' It is therefore entirely appropriate for a court, when conducting claim construction, to rely heavily on the written description for guidance as to the meaning of the claims." (internal citations omitted)).

principle that claims should be interpreted to preserve their validity counsels against such a construction.<sup>25</sup>

Here, as noted above, GE's proposed combination of the "receiver" and "line probing processor" in a single device finds no such support in the specification of the '054 Patent. Likewise, GE's argument that the claimed receiver (or a line probing processor) might be implemented as a software function on a DSP or CPU is entirely unsupported by any intrinsic evidence. Accordingly, no permissible construction of the terms "receiver" and "line probing processor" can allow the combination of those two devices or can include software executing on a general purpose processor.

GE again relies on extrinsic evidence to allege that "[o]ne of ordinary skill in the art at that time was aware that multifunction general processors and digital signal processors are programmed to perform receiver functions."<sup>26</sup> This reliance is unfounded.

First, the evidence on which GE relies expressly fails to mention that a modem, or any components thereof, might be implemented as software on any type of processor. The most that can be said of that extrinsic evidence is that it shows that digital signal processing, in the

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<sup>25</sup> See *North American Vaccine, Inc. v. American Cyanamid Co.*, 7 F.3d 1571, 1577 (Fed. Cir. 1993), cert. denied, 511 U.S. 1069 (1994) (There is no such disclosure of the concept of avoiding crosslinking along the backbone in this patent. Thus, an invention of that breadth does not meet the description requirement. See *Carmen Industries, Inc. v. Wahl*, 724 F.2d 932, 937 n. 5 (Fed. Cir. 1983) ("Claims should be so construed, if possible, as to sustain their validity.") (citations omitted)); accord *Wang Labs., Inc. v. America Online, Inc.*, 197 F.3d 1377, 1382-83 (Fed. Cir. 1999) ("Wang argues that it is irrelevant to the construction of the claims whether the specification contains an enabling description of any bit-mapped decoder . . . . However, the claims are not properly construed to have a meaning or scope that would lead to their invalidity for failure to satisfy the requirements of patentability. Although Wang is correct that a claim is not invalid simply because it embraces subject matter that is not specifically illustrated, in order to be covered by the claims that subject matter must be sufficiently described as the applicant's invention to meet the requirements of section 112." (citations omitted)).

<sup>26</sup> GE's Opening Brief, at 16 (citing Bims Decl., at 7-8, ¶¶ 29-31).

abstract, can be performed by hardware or software. These extrinsic sources do not provide any evidence whatsoever that one skilled in the art would believe that the time-sensitive processing required of a modem might be performed by the relatively slow general purpose processors of that time period.

On the specific topic of modems, Dr. Bims asserts only that, "the company Zilog commercially sold modems as early as 1984 that included a microprocessor that performed digital signal processing (DSP) functions . . ."<sup>27</sup> The support for this assertion appears to be the bare statement on a web page that, in 1984, "CDS 224 2400 bps modem uses ZiLOG Z8 to handle DSP."<sup>28</sup> Dr. Bims fails to explain what a "ZiLOG Z8" is or how this statement might support his assertion. Accordingly, the sum total of Dr. Bims's extrinsic evidence regarding the knowledge of one skilled in the art amounts to abstract assertions about "digital signal processing" generally and an unsupported assertion that modems used a "ZiLOG Z8" in 1984. This extrinsic evidence is of no use in construing the terms "receiver" and "line probing processor."

Second, the scope of the applicant's invention is governed not by what one of skill in the art knew, but what the inventor believed, at the time he filed his application, the invention to be: "It is the responsibility of patent applicants to disclose their inventions adequately. . . . A patent applicant cannot disclose and claim an invention narrowly and then, in the course of an infringement suit, argue effectively that the claims should be construed to cover that which is

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<sup>27</sup> Bims Decl., at 8 ¶ 31.

<sup>28</sup> "History," < [http://www.zilog.com/company/history\\_detail.asp#b](http://www.zilog.com/company/history_detail.asp#b)>, visited May 14, 2008.

neither described nor enabled in the patent."<sup>29</sup> Here GE attempts to do precisely that. The applicant failed entirely even to mention that the devices (including the receiver and the line probing processor) described and claimed in the '054 Patent might be combined and/or implemented as software running on any type of processor, yet GE now claims that the scope of these claim terms must be construed in this way.

In doing so, GE implicitly takes the position that the applicant for the '054 Patent intended his claims to cover modems that combined various devices and/or implemented those devices in software; GE does not explain why, if the applicant intended this coverage, he failed to provide any disclosure of such functionality. GE seems to imply, without justification, that the applicant did not need to provide such disclosure in the '054 Patent, since one of skill in the art purportedly would understand that the disclosure was implicit. If that is true, one wonders why the same inventor, four years later, felt compelled to disclose in a different patent that, "[t]he present invention may be implemented in a digital communication system . . . where a digital signal processor (902) is utilized . . . . The processor typically includes a program storage medium (904) having a computer program to be executed by the digital signal processor . . . ."<sup>30</sup> In light of GE's position that this information would be within the knowledge of one of skill in the art in 1989, its inclusion in a patent filed in 1993 is inexplicable.

The more reasonable inference is that the applicant for the '054 Patent did not believe that his claims covered software running on a processor, whereas four years later, after modem technology had developed further, the inventor believed that such modem functions could be

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<sup>29</sup> *North American Vaccine, Inc.*, 7 F.3d at 1577.

<sup>30</sup> U.S. Patent No. 5,466,758, col. 10, lines. 38-46.

implemented as software. Thus, there is no evidence to support the position that the applicant for the '054 Patent believed that his claims would cover either a combined receiver and line probing processor, or such devices implemented as software running on a processor. GE's proposed construction, therefore, would impermissibly broaden the claims beyond the scope of the applicant's invention.

5. GE cannot now broaden the claim terms to cover software running on a computer's CPU.

Even assuming the Court is persuaded by Dr. Bims's extrinsic evidence to conclude that one skilled in the art might have understood that a "receiver" and/or a "line probing processor" might be implemented as software on a DSP, and that the claims should cover such devices, there is no evidence whatsoever that the applicant, or anyone else, believed in 1989 that any modem functions could be implemented on a computer's CPU.<sup>31</sup> Neither Dr. Bims nor GE introduces one shred of evidence to suggest that one of skill in the art would have understood, in 1989, that the claimed receiver and line probing processor would cover software running on a computer's CPU, rather than as dedicated hardware devices, or, at most, software running on DSP devices.

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<sup>31</sup> While a DSP is a dedicated "digital signal processor" that is specially designed to perform digital signal processing tasks, a CPU is a general purpose processor that is designed to perform a wide variety of tasks in a computer, such as a typical laptop or desktop personal computer. The distinction between a DSP and a CPU is important because most modems today, including a large proportion of the accused products in this litigation, are "soft modems," which employ very little hardware but instead utilize the processing power of the CPU in the computer in which the modem is installed. While common today, these "soft modems" were not introduced until the mid-1990s (several years after the '054 Patent was filed), when technology developed to the point that a CPU was sufficiently powerful to support the processing required for modem functionality, along with other tasks required of a CPU.

Moreover, the Federal Circuit has held, repeatedly, that "[a] claim cannot have different meanings at different times; its meaning must be interpreted as of its effective filing date."<sup>32</sup> More to the point, "when a claim term understood to have a narrow meaning when the application is filed later acquires a broader definition, the literal scope of the term is limited to what it was understood to mean at the time of filing."<sup>33</sup> That is precisely the case here—in 1989, when the '054 Patent was filed, nobody was even close to developing a working software modem. Hence, because there is no credible evidence that anyone would have understood, at the time the '054 Patent was filed, that a receiver or a line probing processor could be implemented as software running on a computer's CPU, GE cannot now assert that the claims should cover such devices.

6. GE's proposed combination of the receiver and the line probing processor would violate the all elements rule.

Finally, GE's proposed construction effectively would "read out" one of the limitations (either the "receiver" or the "line probing processor") of each asserted claim in the '054 Patent. In short, GE cannot claim that a single device in an accused modem satisfies the limitations of both a receiver and a line probing processor. Such a construction would violate the "all elements rule" and cannot be accepted as a permissible construction.<sup>34</sup> Hence, GE's suggestion—that a

<sup>32</sup> *PC Connector Solutions LLC v. SmartDisk Corp.*, 406 F.3d 1359, 1363 (Fed. Cir. 2005) (compiling cases).

<sup>33</sup> *Kopykake Enterprises, Inc. v. Lucks Co.*, 264 F.3d 1377, 1383 (Fed. Cir. 2001).

<sup>34</sup> See *Crown Packaging Tech., Inc. v. Rexam Beverage Can Co.*, 531 F. Supp. 2d 629, 639 (D. Del. 2008) ("It is well settled that each element of a claim is material and essential, and that in order for a court to find infringement, the plaintiff must show the presence of every element or its substantial equivalent in the accused device." (quoting *Zygo Corp. v. Wyko Corp.*, 79 F.3d 1563, 1568 (Fed. Cir. 1996)); accord *Inpro II Licensing, S.A.R.L., v. T-Mobile USA, Inc.*, 450 F.3d 1350, 1357-58 (2006) ("To establish infringement, every element and limitation of the claim must be present in the accused device, literally or by equivalent.")

receiver and a line probing processor might be combined in the same device—must be discarded for this additional reason.

Rather than seeking to import limitations from the '054 Patent's specification into the claims, as GE accuses, Agere's proposed construction of the terms "receiver" and "line probing processor" comports with the scope of the '054 Patent's disclosure (thereby preserving the validity of the claims), maintains the materiality of all claim elements, and provides appropriate guidance to the trier of fact on the meaning of the terms at issue. Notwithstanding GE's dubious resort to extrinsic evidence, GE's proposed constructions fail to adhere to any of these principles. Accordingly, the Court should adopt Agere's proposed constructions of the terms "receiver" and "line probing processor."

**B. "Selector"**

<b>Agere's Proposed Construction</b>	<b>GE's Proposed Construction</b>
Invalid under 35 U.S.C. § 112, ¶¶ 1, 2	"Plain Meaning" ( <i>structure that runs a choosing algorithm</i> )

GE proposes that the Court adopt the "plain meaning" of the term "selector,"<sup>35</sup> despite the fact that the '054 Patent provides no enabling disclosure of any such "selector." Once again, GE supplements the "plain meaning" of the claim term at issue with its own definition: "structure that runs a choosing algorithm."<sup>36</sup> Unfortunately, this term is of no help in identifying what "structure" disclosed by the '054 Patent is supposed to implement the choosing algorithm.

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<sup>35</sup> GE's Opening Brief, at 18.

<sup>36</sup> *Id.*

Regarding such "structure," GE argues only that "the specification discloses the implementation by the line probing processor of a decision or choosing algorithm to perform the selection."<sup>37</sup> Apparently, GE would have the Court collapse the recited "selector" into the "line probing processor," which, GE asserts, really should be included in the "receiver."<sup>38</sup> Hence, vitiating yet another claim element, GE effectively argues, notwithstanding the fact that each asserted claim recites three distinct limitations, that the Court should construe the claims as having a single limitation each. This cannot be correct.<sup>39</sup>

In fact, the '054 Patent discloses no element in a single modem that performs the functions ascribed to a selector by the claims of the '054 Patent. Instead, the '054 Patent teaches that the local and remote modems engage in a collaborative process, by which they exchange a decision matrix and agree on transmission parameters.<sup>40</sup> Accordingly, since the '054 Patent fails to provide an enabling disclosure any "selector," as recited by Claims 1, 12 and 46, those claims fail to comply with the enablement requirement of 35 U.S.C. § 112, ¶ 1 and are indefinite under § 112, ¶ 2; hence, the term "selector" cannot be construed.<sup>41</sup>

In the event the Court decides to adopt a construction of the term "selector," it should discount GE's argument that the "plain" meaning of the term "selector" includes an amorphous

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<sup>37</sup> *Id.*

<sup>38</sup> *See supra* Sections II.A.1-2.

<sup>39</sup> It is notable that, other than the line probing processor, GE can find no disclosure in the '054 Patent of any purported "structure" that performs the "choosing algorithm" proposed by GE.

<sup>40</sup> *See* '054 Patent, col. 13, line 23 – column 14, line 7.

<sup>41</sup> GE argues that the '054 Patent does mention a "selector" in the summary section. GE's Opening Brief, at 19. As noted in Agere's Opening Brief, however, that use of the term merely parrots the claims and provides no enabling disclosure of a selector. *See* Agere's Opening Brief, at 11.

"structure" or that the selector might be the line probing processor. As noted *supra* Section II.A.1-2, there is no support in the '054 Patent for GE's asserted "structure" (which presumably includes software running on a DSP or CPU), and, for the reasons mentioned above, the term "selector," like the terms "receiver" and "line probing processor," cannot be construed to cover anything but a discrete hardware device. Similarly, the Court should not countenance GE's attempted vitiation of the "selector" limitation by construing that term to mean a line probing processor.

**C. "For selecting one of the plurality of frequency bands [or bit rates]"**

<b>Agere's Proposed Construction (For selecting one of the plurality of frequency bands)</b>	<b>GE's Proposed Construction (For selecting one of the plurality of frequency bands)</b>
<i>for determining a frequency band to be used for receiving a modulated signal from the remote device, based upon the channel characteristics measured by the line probing processor</i>	"Plain Meaning"

<b>Agere's Proposed Construction (For selecting one of the plurality of bit rates)</b>	<b>GE's Proposed Construction (For selecting one of the plurality of bit rates)</b>
<i>for determining a bit rate to be used for receiving a modulated signal from the remote device, based upon the channel characteristics measured by the line probing processor</i>	"Plain Meaning"

With regard to the claim terms "for selecting one of the plurality of frequency bands" and "for selecting one of the plurality of bit rates," GE takes pains to pillory Agere for "merely attempting to introduce redundancy or confusion and/ or improperly import limitations into the

asserted claims."<sup>42</sup> In so doing, GE misinterprets Agere's proposed construction of these terms (and apparently Agere's motive as well).

Agere's proposed construction merely highlights the requirement that the frequency band and bit rate are selected based upon the channel characteristics measured by the line probing processor.<sup>43</sup> This construction is required in order to give the term "measured characteristics" antecedent basis.

Apparently confused by Agere's proposed construction, GE argues that Agere attempts to "impos[e] on the claim a requirement that the selecting be performed 'by the line probing processor' (and hid[e] that it seeks to do so)."<sup>44</sup> This is simply incorrect. Nothing in Agere's proposed construction of the "selecting" terms requires that the selecting be done by the line probing processor.<sup>45</sup> Instead, a careful reading of Agere's proposed construction reveals that the term "line probing processor" refers only to the measurement of the channel characteristics (as specifically recited in each claim), not to any selecting function. It is difficult to see how GE extracts from Agere's proposed phrase, "based upon the channel characteristics measured by the line probing processor," some "requirement that the selecting be performed 'by the line probing processor' . . . ."

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<sup>42</sup> GE's Opening Brief, at 20.

<sup>43</sup> See Agere's Opening Brief, at 16-17.

<sup>44</sup> GE's Opening Brief, at 22.

<sup>45</sup> Coincidentally, while accusing Agere of "imposing" on the term "selecting," GE itself argues that it is the line probing processor that functions as a selector. See GE's Opening Brief at 19 ("[T]he specification discloses the implementation by the line probing processor of a decision or choosing algorithm to perform the selecting . . . ."). Rather than "imposing" such a requirement, Agere's position is that such a construction vitiates the "selector" term. See *supra* Section II.B.

Other than that, the parties appear to be in substantial agreement on these terms. GE objects to the term "determining," preferring instead the term "selecting." Agere's position is that using the term "selecting" in the construction is circular, since that is the term being construed, but Agere can see no material difference between the two terms and is willing to substitute the term "selecting" for "determining" in its proposed construction.

GE further objects to the inclusion of the phrase "to be used for receiving a modulated signal from the remote device," arguing essentially that this term is surplusage. Agere is willing to concede that the addition of this phrase is redundant; in proposing its construction, Agere merely seeks to have the Court clarify that the selecting of either a frequency band or a bit rate is based upon the channel characteristics measured by the line probing processor, because the claims, as written, are somewhat ambiguous in this respect.<sup>46</sup> Rewriting the entire claim element seems to be the most direct way to accomplish that construction. Agere, however, is willing to accept an alternative construction of the "selecting" terms that specifies that the frequency band or bit rate is selected based upon the channel characteristics measured by the line probing processor.

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<sup>46</sup> Agere also believes that the term "one of the plurality of frequency bands," as used in Claim 12, should be construed to be consistent with the use of that term in Claim 1: "one of the plurality of frequency bands to be used for receiving a modulated signal from a remote device." See Agere's Opening Brief, at 17.

### III. CLAIM TERMS – U.S. PATENT NO. 5,428,641 (THE "'641 PATENT")

#### A. "Constellation"

Agere's Proposed Construction	GE's Proposed Construction
<i>the set of 2<sup>n</sup> multi-dimensional signal points used to represent a mapping frame of n input data bits</i>	<i>a finite set of points in space</i>

GE's proposed construction of the term "constellation" is overly broad, is unsupported by intrinsic evidence, and adds little to a fact finder's understanding of the '641 Patent. GE's construction does not provide the reader any information regarding how constellation points are used, why they are used, or what they are used for. GE seeks an overly broad construction of a term critical to understanding the scope of the patent in light of referenced prior art techniques.<sup>47</sup> In short, GE's construction does not provide the reader with any background or substance - it is effectively equivalent to no construction at all. Such an overly broad definition is not an appropriate way to interpret what GE admittedly considers "a term of art in the modem field."<sup>48</sup>

GE purports to support its construction entirely through extrinsic evidence, without regard to any intrinsic evidence within the '641 Patent. In particular, the '641 Patent describes only multi-dimensional constellations and does not even contemplate one-dimensional constellations; GE's only support for a construction broadening this term to include one-dimensional constellations are unsupported assertions from a declaration by its own expert.<sup>49</sup> GE

<sup>47</sup> See '641 Patent, col. 1, l. 45 - col. 2, l. 25.

<sup>48</sup> GE's Opening Brief, at. 24.

<sup>49</sup> *Id.* at 24-25 (citing Bims Decl. ¶¶ 45-46).

admits that "[h]igher dimensional constellations are also used";<sup>50</sup> however, GE disagrees with Agere's construction, which helpfully includes the term "multi-dimensional" to explain use of the term constellation within the invention. Thus, GE's position is inconsistent, overly broad, and not useful for a jury or the Court.

GE's reliance on extrinsic evidence highlights the unreliability of the use of such evidence during claim construction. GE takes Dr. Tretter's definition out of context, and as predicted by the Federal Circuit, provides the Court with a one-sided view of the available extrinsic evidence.<sup>51</sup> Again, without support from intrinsic evidence, this extrinsic evidence is of little value in explaining the meaning of claim terms. Agere can equally point to extrinsic evidence from reliable sources that support its construction. For example, Exhibits A through E hereto contain excerpts from prominent textbooks that define the term "constellation" in support of Agere's construction. However, these extrinsic sources pale in comparison to the intrinsic evidence provided by the '641 Patent itself. Both parties can hire experts to support their positions, and both parties can invoke technical references and dictionaries to support their constructions. Nonetheless, Agere has chosen to not engage in a battle of the references, but instead to focus on the evidence the Federal Circuit deems the most reliable for claim construction -- intrinsic evidence from the patent itself.

GE oversimplifies the term constellation, baldly arguing that, "since that mathematical nuance is unnecessary to resolve any issues in the case, . . . there is no need to burden the jury

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<sup>50</sup> *Id.*

<sup>51</sup> *Cf. Phillips*, 415 F.3d at 1318.

with it."<sup>52</sup> This assertion is patently false. A review of the specification and claims of the '641 Patent reveal that the number of points in a constellation and the ability to map frames of data without constellation switching is at the heart of the invention.<sup>53</sup> In the specification, the inventor describes his invention as an improvement that allows a modem to operate at a fractional bit rate without changing between constellations with different numbers of points.<sup>54</sup> A deeper reading of this patent shows that within mapping frames, the number of points in the chosen constellation is necessarily related to the number of bits in each frame. These are not nuances but the essence of the purported invention. Disregarding them does a great disservice to any fact finder tasked applying the claims of the '641 Patent. The technology of the '641 Patent is inherently complex, and GE should not be allowed to oversimplify the issues to lessen its burden in this matter.

While there is ample intrinsic support within the '641 Patent to form a suitable and helpful definition,<sup>55</sup> GE ignores this evidence. Instead GE selectively chooses from extrinsic evidence as necessary to support its overbroad and ineffective definition of the term "constellation." Instead of searching for self-serving extrinsic evidence and adding self-serving declarations from its expert, Agere has proposed an informed and fair construction based on the intrinsic evidence of the '641 Patent. Accordingly, the Court should adopt Agere's proposal.

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<sup>52</sup> GE's Opening Brief, p. 25.

<sup>53</sup> See '641 Patent, col. 1, l. 45 - col. 2, l. 25; claims 1-8.

<sup>54</sup> *Id.*, col. 1, l. 45 - col. 2, l. 25.

<sup>55</sup> See Agere's Opening Brief, at. 21-22.

**B. "Constellation Switching"**

Agere's Proposed Construction	GE's Proposed Construction
<p>The preamble of claims 1, 3, 5, and 7 is limiting.</p> <p>"constellation switching" means <i>using constellations with varying numbers of points for mapping multiple frames of data bits</i></p>	<p>The preamble of claims 1, 3, 5, and 7 is not limiting.</p> <p>If the preamble is found to be limiting, "constellation switching" means <i>a change between two constellations having different numbers of points</i></p>

GE mistakenly characterizes the preamble of the asserted claims of the '641 Patent as not limiting those claims (*i.e.*, does not serve a claim limitation), alleging that the claims elements describe a structurally complete invention. For this position, GE cites *Symantec Corp. v. Computer Assocs. Int'l, Inc.*,<sup>56</sup> which relies on *Catalina Marketing Int'l, Inc. v. Coolsavings.com, Inc.*,<sup>57</sup> also cited by GE.<sup>58</sup> However, GE selectively chooses one of several tests adopted by the Federal Circuit to determine when a preamble should be regarded as limiting, while failing to recognize the importance of the preamble when read in conjunction with the specification of the patent. In *Catalina*, the case on which GE relies, the Federal Circuit also noted that the preamble for a claim term should be construed as a claim limitation if it recites additional features underscored as important by the specification.<sup>59</sup>

In this case, the specification of the '641 Patent clearly demonstrates that the inventor believed that the point of the invention was to avoid "constellation switching." First, the

<sup>56</sup> 522 F.3d 1279 (Fed. Cir. 2008).

<sup>57</sup> 289 F.3d 801 (Fed. Cir. 2002).

<sup>58</sup> See GE's Opening Brief, at 25-26.

<sup>59</sup> *Catalina Marketing Int'l Inc.*, 289 F.3d at 808.

inventor clearly recognizes methods from prior art that accomplish the goal of his invention through the use of "constellation switching."<sup>60</sup> The inventor then devotes a portion of the background section to explaining the disadvantages of constellation switching.<sup>61</sup> The inventor goes on to explain the purpose of the present invention, stating, "[h]ence, there is a need for a frame-mapping device and method which maps data that is transmitted at fractional bits per frame rate such that the implementation difficulties of constellation switching are avoided."<sup>62</sup> Thus, the inventor distinguishes his invention from the prior art by the fact that the invention can operate without constellation switching. This discussion shows the central importance of avoiding constellation switching to the invention disclosed and claimed by the '641 Patent. As the Federal Circuit has held, when the preamble recites structure or steps that are deemed important in the specification, the preamble limits the claim's scope.<sup>63</sup> This is exactly the case for the '641 Patent—the preamble of each asserted claim highlights the importance of a method or device that avoids constellation switching, and the claims are directed to just such a device.

GE argues that the preamble's discussion of constellation switching reflects an intended use for the invention, and thus should not limit the claims. The avoidance of constellation switching, however, is not merely an intended use -- it is an integral feature of the invention. The inventor of the '641 Patent claims novelty precisely because the invention purports to teach a way to send a fractional average number of bits per frame without constellation switching. Again, this is evidenced by the inventor's efforts to distinguish the invention from prior art that

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<sup>60</sup> '641 Patent, col. 1, l. 45 - col. 2, l. 25.

<sup>61</sup> *Id.*

<sup>62</sup> *Id.*, col. 2, ll. 22-25.

<sup>63</sup> *Catalina Marketing Int'l Inc.*, 289 F.3d at 808.

relies upon constellation switching to send fractional number of bits per frame.<sup>64</sup> Thus, the preamble's reference to constellation switching is not merely a suggested use, but instead a limitation to the claims of the patent.

**C. "Can Be"**

Agere's Proposed Construction	GE's Proposed Construction
<p>The preamble of claims 1 and 3 is limiting.</p> <p>"can be" means <i>are or must be</i></p> <p>As used in the preamble, this term creates a required or limiting condition for the claim. Thus, the phrase "can be transmitted without constellation switching" must be read as "are transmitted without constellation switching."</p>	<p>The preamble of claims 1 and 3 is not limiting.</p> <p>If the preamble is found to be limiting, "can be" should be given its plain meaning - that is, it cannot be broken down any more.</p>

As discussed in Agere's Opening Brief, and *supra* Section III.B, the preamble of Claims 1 and 3 of the '641 Patent must be interpreted as limiting those claims. The inventor of the '641 Patent viewed the novelty of the invention as a method to send a fractional number of bits per frame without constellation switching.<sup>65</sup> Accordingly, to be consistent with a fair reading of the intrinsic evidence, the preamble must be construed as limiting with respect to its inclusion of constellation switching.

GE asserts that the very nature of the term "can be" is permissive, not mandatory. While this may be true when the term stands alone, the reader must consider the context of the term in the case of the '641 Patent. Claims 1 and 3 each recite "...can be transmitted without

<sup>64</sup> '641 Patent, col. 1, l. 45 - col. 2, l. 25.

<sup>65</sup> *Id.*

constellation switching..."<sup>66</sup> The inventor's usage of "can be" does not indicate a permissive or optional characteristic, but rather an explanation of the utility or novelty of the invention, which is an essential part of the invention. For example, the quoted language above could be changed to "permits transmission without constellation switching" or "allows transmission without constellation switching" without affecting the meaning of that language. Consider, however, substitution of another permissive term "might be": "such that a fractional number of bits might be transmitted without constellation switching." This phrase has a completely different (and indefinite) meaning from the actual claim language, and this contrast highlights the failings of GE's approach.

Hence, the only reasonable interpretation of the term "can be," in this context, is not as permissive language but instead as being equivalent to the term "are," especially considering the specification's discussion of the importance to the invention of avoiding constellation switching.<sup>67</sup> Thus, while the term "can be" may generally be permissive, when read in light of the inventor's understanding of the invention (a device that permits transmission of data at fractional bit rates, without constellation switching), the term recites a necessary aspect of the invention.

GE also argues that the doctrine of claim differentiation supports its position that the term "can be" is not mandatory. GE's position is that because the word "are" is used in other claims, the inventor must have intended to use "can be" as permissive in Claims 1 and 3. This might be true if the inclusion of the term "can be" was the only difference between Claims 1 and 3, on the

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<sup>66</sup> '641 Patent, claims 1 and 3.

<sup>67</sup> '641 Patent, col. 1, l. 45 - col. 2, l. 25.

one hand, and Claims 5 and 7, on the other.<sup>68</sup> That is not the case, however. For instance, while Claims 1 and 3 recite "selecting a number of bits for each frame . . . , where  $Q=N*B/S$ , B is a predetermined bit rate, and S is a predetermined symbol rate," Claim 5 and 7 recite "selecting a number of bits for each from, according to a predetermined pattern." Similarly, Claims 1 and 3 recite "mapping the frame bits such that for MSB=0, one of the  $2^{J-1}$  N-point combinations with least average energy is selected from the signal constellation," while Claims 5 and 7 recite "mapping the frame bits such that for MSB=0, one of the  $2^{J-1}$  N-point combinations with least average energy is selected from the 2J possible combinations."<sup>69</sup> Given these differences between the claims, GE's claim differentiation argument has no bearing on the proper construction of the claims.

Accordingly, the proper construction of the term "can be" should be ascertained by reading the specification to determine what the inventor considered his invention. The inventor sought to proffer a technique of frame mapping for fractional bit rates without constellation switching. To read out the requirement of not switching constellations is to ignore the plain intent of the inventor and a central aspect of the invention.

<sup>68</sup> See *Kraft Foods, Inc. v. International Trading Co.*, 203 F.3d 1362, 1368 (Fed. Cir. 2000) ("[C]laim differentiation only creates a presumption that each claim in a patent has a different scope; it is not a hard and fast rule of construction. . . . Moreover, that the claims are presumed to differ in scope does not mean that every limitation must be distinguished from its counterpart in another claim, but only that at least one limitation must differ." (emphasis added, citations and internal quotation marks omitted) (quoting *Comark Comm's, Inc. v. Harris Corp.*, 156 F.3d 1182, 1186 (Fed.Cir.1998) and citing *Mantech Envtl. Corp. v. Hudson Envtl. Servs.*, 152 F.3d 1368, 1376 (Fed.Cir.1998)).

<sup>69</sup> 641 Patent, claims. 1, 3, 5, 7 (differences emphasized).

**D. "Frame Selector," "Zero Insertion Unit," and "Signal Constellation Selector/Mapper"**

Like the terms "receiver," "line probing processor" and "selector" of the '054 Patent, GE proposes for the terms "Frame Selector," "Zero Insertion Unit," and "Signal Constellation Selector/Mapper" constructions that have a "structure" (which, as GE defines that term in its Opening Brief, includes software running on a DSP or CPU).<sup>70</sup> Similar to its proposed constructions of certain terms in the '054 Patent, GE relies on declarations from its expert that at the time of the application for the '641 Patent, those skilled in the art knew that the invention could be implemented in software running on a DSP or a CPU. However, the '641 Patent, like the '054 Patent, omits any mention that these devices might be implemented as software running on any type of processor. For the reasons discussed supra Section II.A, GE's proposed constructions are similarly unsuitable here.

Accordingly, because GE's proposed constructions would violate the all elements rule (by aggregating the frame selector, zero insertion unit and signal constellation selector/mapper into a single limitation) and find no support in either the intrinsic or extrinsic evidence of record, the Court should adopt Agere's proposed definitions of those terms. At the very least, as discussed supra Section II.A.5, GE cannot now broaden the constructions of these terms to include software running on a computer's CPU.

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<sup>70</sup> See GE's Opening Brief, at 28, 30, 31.

**E. "Operably Coupled"**

<b>Agere's Proposed Construction</b>	<b>GE's Proposed Construction</b>
<i>physically connected to allow inter-operation</i>	<i>whose input is derived from the output of another structure</i>

In its construction of the term "operably coupled," GE ignores the plain meaning of the term. The term "operably coupled" has little or nothing to do with "input" and "output" of "structures." Such a construction simply ignores the standard usage of the terms "operably" and "coupled." Clearly, GE's proposed construction is not driven by a desire to be faithful to the claim language, but rather reflects an effort to shoehorn the term "operably coupled" into GE's novel "structure" paradigm. Neither position finds any support in the evidence of record.

GE states that its proposed construction of the term "operably coupled" is "consistent with the intrinsic and extrinsic evidence," yet GE offers no citation or explanation regarding how its construction is consistent with intrinsic evidence. Furthermore, the only extrinsic evidence offered by GE is an unsupported declaration of its own expert as to the implementation of modems in software.<sup>71</sup> In contrast, Agere's proposed construction finds support in both the intrinsic evidence and, for what it's worth, the only extrinsic evidence of record.<sup>72</sup> The Court, therefore, should adopt Agere's proposed construction of the term "operably coupled."

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<sup>71</sup> See *id.*, at 32 (citing Bims Decl., ¶¶ 53, 55).

<sup>72</sup> See Agere's Opening Brief, at 28 n. 75.

#### IV. CLAIM TERMS - U.S. PATENT NO. 6,198,776 (THE "'776 PATENT")

##### A. "Quantization Device"

Agere's Proposed Construction	GE's Proposed Construction
<i>a device that converts a signal with a continuum of amplitudes to a set of discrete values, including linear, A-law, <math>\mu</math>-law or any other analog to digital conversion</i>	<i>a device that quantizes a signal</i>

GE proposes a construction of the term "quantization device" that not only is completely unhelpful to the trier of fact, but also is inconsistent with the intrinsic evidence from the '776 Patent. In fact, GE's own argument supports Agere's proposed construction, rather than GE's proposal. First, GE accurately points out that a quantization device is "described in the specification in connection with  $\mu$ -law or A-law."<sup>73</sup> Accordingly, Agere has proposed inclusion, by way of example, the A-law and  $\mu$ -law codecs described by the specification in its construction of the term "quantization device." Furthermore, to avoid narrowing the term without proper support from the specification, Agere also included the caveat of "any other analog to digital conversion."

GE argues that the term "quantization device" should not be "limited" to analog to digital conversions.<sup>74</sup> However GE fails to explain any relevant context in which a quantization device operates other than to convert analog (continuous) to digital (discrete) values. This is the essence of quantization. Further, the intrinsic evidence is in accord with this interpretation. Even GE acknowledges that the specification discloses "quantizer 103 quantizes the incoming analog

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<sup>73</sup> GE's Opening Brief, at 34.

<sup>74</sup> *Id.*, at 35.

signal into octets or eight-bit digital words."<sup>75</sup> Thus, in GE's own explanation, based on the specification, GE concedes that the quantizer performs an analog to digital conversion. Thus, there is no basis within the specification to exclude the analog to digital aspect of Agere's construction.

Agere's proposed construction of the term "quantization device" is concise, explanatory, and based on directly intrinsic evidence from the '776 Patent. By contrast, GE's proposed construction, while perhaps accurate, is overly ambiguous in light of the intrinsic evidence and provides no guidance to the fact finder. Accordingly, Agere's definition should be adopted in lieu of the construction proffered by GE.

**B. "Upstream PCM Data Transmission" and "Analog Pulse Code Modulation (PCM) Modem"**

Agere has revisited its analysis of Claim 30, and while Agere disagrees with GE's proposed construction of the terms "analog pulse code modulation (PCM) modem" and "upstream PCM data transmission," in light of the evidence, Agere now agrees that the preamble of Claim 30 merely states an intended use and therefore does not limit that claim.<sup>76</sup> Accordingly, Agere now agrees that the terms "analog pulse code modulation (PCM) modem" and "upstream PCM data transmission" need not be construed.

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<sup>75</sup> *Id.*

<sup>76</sup> The differences between the preamble of Claim 30 of the '776 Patent and the preambles of the claims of the '641 Patent are instructive in this regard. While the preamble of Claim 30 merely recites an intended use to provide a context for the elements of that claim, the preambles of the claims of the '641 Patent recite necessary features of the invention and therefore limit those claims. Compare Section III.B, *supra*.

**V. CONCLUSION**

Agere respectfully submits that its proposed constructions for the limitations of the asserted claims of the '054 Patent, the '641 Patent, and the '776 Patent are supported by the intrinsic (and extrinsic) evidence of record and should be adopted by the Court as a matter of law.

Respectfully submitted,

YOUNG CONAWAY STARGATT & TAYLOR, LLP



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John W. Shaw (No. 3362)

jshaw@ycst.com

Jeffrey T. Castellano (No. 4837)

jcastellano@ycst.com

The Brandywine Building

1000 West Street, 17<sup>th</sup> Floor

Wilmington, DE 19899-0391

302-571-6600

*Attorneys for Defendant Agere Systems Inc.*

OF COUNSEL:

David E. Sipiora

Ian L. Saffer

Chad E. King

TOWNSEND AND TOWNSEND AND CREW, LLP

1200 17<sup>th</sup> Street, Suite 2700

Denver, CO 80202

303-571-4000

Dated: May 16, 2008

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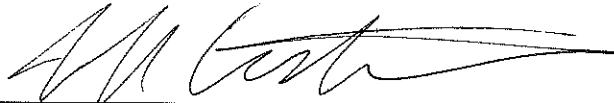
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**BY E-MAIL**

Joel E. Freed, Esquire  
Brian E. Ferguson, Esquire  
Mark A. Davis, Esquire  
D. Sean Trainor  
McDermott Will & Emery LLP  
600 13<sup>th</sup> Street, N.W.  
Washington, DC 20005  
jfreed@mwe.com  
bferguson@mwe.com  
madavis@mwe.com  
dtrainor@mwe.com

Edwin H. Wheeler, Esquire  
McDermott Will & Emery LLP  
3150 Porter Drive  
Palo Alto, CA 94304  
mwheeler@mwe.com

YOUNG CONAWAY STARGATT & TAYLOR, LLP



---

Josy W. Ingersoll (No. 1088)  
jingersoll@ycst.com  
John W. Shaw (No. 3362)  
jshaw@ycst.com  
Jeffrey T. Castellano (No. 4837)  
jcastellano@ycst.com  
The Brandywine Building  
1000 West Street, 17th Floor  
Wilmington, Delaware 19801  
(302) 571-6600

Attorneys for Agere Systems Inc.

# EXHIBIT A

# Principles of Digital Communication

ROBERT G. GALLAGER

Massachusetts Institute of Technology

2008

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In most cases of modulation, the set of waveforms  $\phi_1(t), \phi_2(t), \dots$  in (6.1) will be chosen not as a basis for  $\mathcal{L}_2$  but as a basis for some subspace<sup>2</sup> of  $\mathcal{L}_2$  such as the set of functions that are baseband-limited to some frequency  $W_b$  or passband-limited to some range of frequencies. In some cases, it will also be desirable to use a sequence of waveforms that are not orthonormal.

We can view the mapping from bits to numerical signals and the conversion of signals to a waveform as separate layers. The demodulator then maps the received waveform to a sequence of received signals, which is then mapped to a bit sequence, hopefully equal to the input bit sequence. A major objective in designing the modulator and demodulator is to maximize the rate at which bits enter the encoder, subject to the need to retrieve the original bit stream with a suitably small error rate. Usually this must be done subject to constraints on the transmitted power and bandwidth. In practice there are also constraints on delay, complexity, compatibility with standards, etc., but these need not be a major focus here.

**Example 6.1.1** As a particularly simple example, suppose a sequence of binary symbols enters the encoder at  $T$ -spaced instants of time. These symbols can be mapped into real numbers using the mapping  $0 \rightarrow +1$  and  $1 \rightarrow -1$ . The resulting sequence  $u_1, u_2, \dots$  of real numbers is then mapped into a transmitted waveform given by

$$u(t) = \sum_k u_k \operatorname{sinc}\left(\frac{t}{T} - k\right). \quad (6.2)$$

This is baseband-limited to  $W_b = 1/2T$ . At the receiver, in the absence of noise, attenuation, and other imperfections, the received waveform is  $u(t)$ . This can be sampled at times  $T, 2T, \dots$  to retrieve  $u_1, u_2, \dots$ , which can be decoded into the original binary symbols.

The above example contains rudimentary forms of the two layers discussed above. The first is the mapping of binary symbols into numerical signals<sup>3</sup> and the second is the conversion of the sequence of signals into a waveform. In general, the set of  $T$ -spaced sinc functions in (6.2) can be replaced by any other set of orthogonal functions (or even nonorthogonal functions). Also, the mapping  $0 \rightarrow +1, 1 \rightarrow -1$  can be generalized by segmenting the binary stream into  $b$ -tuples of binary symbols, which can then be mapped into  $n$ -tuples of real or complex numbers. The set of  $2^b$  possible  $n$ -tuples resulting from this mapping is called a *signal constellation*.

<sup>2</sup> Equivalently,  $\phi_1(t), \phi_2(t), \dots$  can be chosen as a basis of  $\mathcal{L}_2$ , but the set of indices for which  $x_j$  is allowed to be nonzero can be restricted.

<sup>3</sup> The word *signal* is often used in the communication literature to refer to symbols, vectors, waveforms, or almost anything else. Here we use it only to refer to real or complex numbers (or  $n$ -tuples of numbers) in situations where the numerical properties are important. For example, in (6.2) the *signals* (numerical values)  $u_1, u_2, \dots$  determine the real-valued waveform  $u(t)$ , whereas the binary input *symbols* could be 'Alice' and 'Bob' as easily as 0 and 1.

Figure 6.1. Layers of

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# EXHIBIT B

*This book  
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It has been predicted that the arrival  
of this all digital telecommunication network

TABLE 4.1 Phase Changes for Differential QPM

Dibit	Phase Change (°)	
	V.26	V.22, etc.
00	0	90
01	90	0
11	180	270
10	270	180

*An Argument for Sometimes Not Using Differential Phase Encoding.* As we shall see in Section 5.7, synchrodyne demodulation and decoding of a signal that has been differentially phase encoded causes bit errors to occur in pairs, because if noise causes a received point to move into another quadrant, then both that symbol and the next will have one bit in error. Some error correcting methods are not able to deal with such correlated errors, and differential phase encoding must be eschewed. Then very special techniques are needed to establish a phase reference in the receiver.

#### 4.2.3 Multipoint Constellations

In the one-dimensional baseband case, the symbol rate can be reduced by a factor of  $M$  by encoding  $M$  bits into  $L (= 2^M)$  equally probable levels. Similarly,  $M$  bits can now be encoded into  $L^2$  points in a two-dimensional space.

Much work has been done to devise multipoint constellations [TW&D] that are optimum in some specified conditions. If added Gaussian noise is the only impairment, then for  $L$  large, the optimum constellations are based on an equilateral-triangular grid, which packs a set of points into a minimum area (minimum total power) while maintaining a given distance between neighbors. To deal with other impairments such as phase jitter (see Sections 1.4.2.8 and 6.4.2.1) more complicated constellations, such as that of V.29 [F&G], have been devised. However, each of these constellations has some or all of the following disadvantages: they (1) are difficult to generate and even more difficult to detect optimally in the receiver, (2) do not satisfy the quadrantal invariance requirement discussed in Section 4.3.2, or (3) are patented.

Consequently, if  $M$  is even, then square constellations, in which  $M/2$  bits are used independently for each dimension, are now most often used.

*Constellations for  $M$  Odd.* In these cases a simple square is not possible, and the constellations become more complicated. For  $M = 3$ , three different ones have been used: the eight-phase configuration in Fig. 4.4a and the two "stars" in Figs. 4.4b and 4.4c. The star in Fig. 4.4b is theoretically preferable because its total power is less for the same minimum distance between points. However, the transmit signal is more difficult to generate by analog techniques because the  $x_p$  and  $x_q$  coordinates are not integrally related; furthermore, optimum decisions

in the receiver cannot be made. Consequently, the star in Fig. 4.4c is recommended and is not needed.

For  $M = 5$  and 7, the alphabet is codified by Ungerboeck, [U].

**4.2.3.1 Practical Constellations.** If more than one speed, it is de-

## 4.2 QUADRATURE MODULATION AND KEYING 83

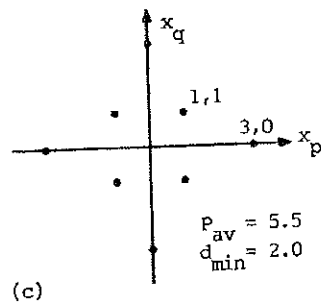
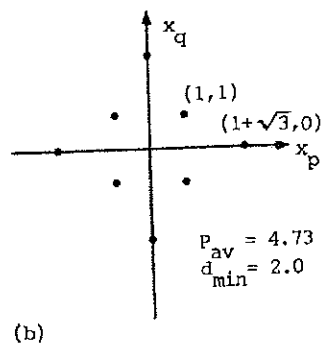
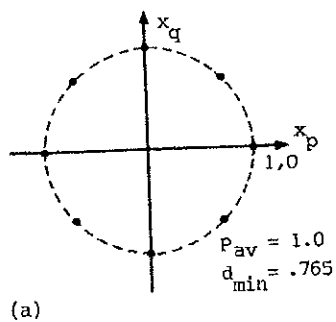


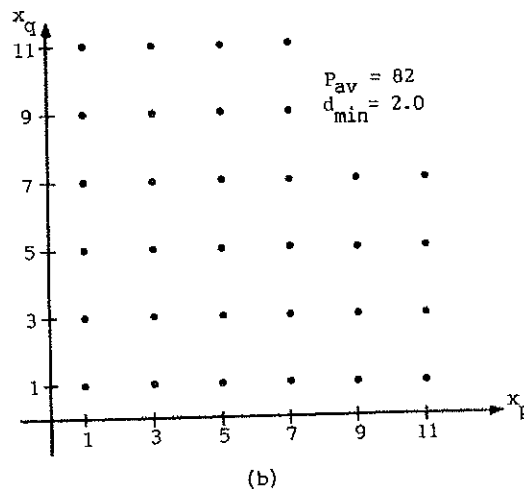
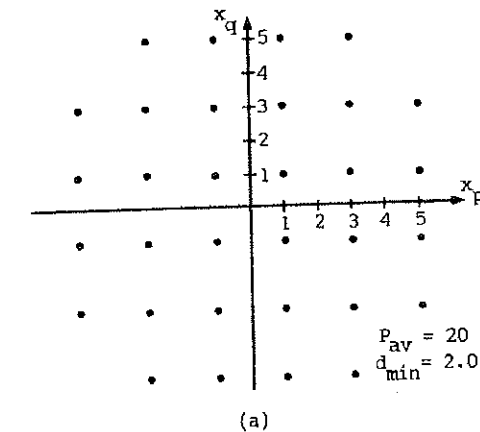
Figure 4.4 Eight-point constellations.

in the receiver cannot be made independently in each dimension. Consequently, the star in Fig. 4.4c was chosen for the 4800 bit/s fall-back mode of V.29 and is recommended when constant amplitude (pure phase modulation) is not needed.

For  $M = 5$  and 7, the almost square "crosses" in Fig. 4.5 were proposed and codified by Ungerboeck, [Un4].

**4.2.3.1 Practical Constellations.** For modems that may have to transmit at more than one speed, it is desirable that all the points of each constellation lie on

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**Figure 4.5** Nonsquare ( $B$  odd) constellations: (a) 32-point "cross"; (b) one quadrant of a 128-point cross.

a simple integer grid and that each set have approximately the same average energy. These desiderata can be almost achieved by rotating the sets with  $M$  odd by  $45^\circ$ , expanding the basic four-point set so that the minimum distance between points is 8, and then reducing this distance by a factor of  $\sqrt{2}$  each time  $M$  is increased by one. One quadrant of each of the resultant sequence of constellations is shown in Figs. 4.6a–4.6e.

These preferred constellations all have quadrantal or rotational invariance, and the two bits out of each block of  $M$  bits (by convention, the first two) that define the quadrant of the transmitted signal must be differentially encoded as described in Section 4.2.2. The other bits must then be assigned to the points in

each quadrant in such a constellation is rotated constellation—shrunk to  $\sqrt{2}$  and  $\sqrt{32}$  is shown in Figs. 4.6a,  $\sqrt{10}$ , and  $\sqrt{18}$  for the first and 11, respectively.

#### 4.2.3.2 Error Rates for power in each dimension:

and since for low error rate the error rate in each dimension

$$\mathcal{P}_e =$$

The factor  $2N_0/T$  is the i.e.,  $f_c - f_s/2$  and  $(f_c - f_s)$  can be denoted by  $P_N$ . For bits, and, with Gray encoding, the error rate is

$$\text{BER} =$$

Recognizing that the number of one-dimensional base points (4.7) and (4.10) are the same, the QAM system shown in Fig. 4.5 is the same as the one shown in Fig. 4.6.

#### 4.2.3.3 Error Rates for constellations—those for which the error rate is determined by the distance to the nearest neighbor is mainly determined by the distance to the nearest neighbor that are thus separated. The error rate is determined by

and conversely, by the average

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To BARBARA, RACH  
for their love, encourag

To MARY, ANN, JERE  
with special acknowled  
MARGIE and NIKI.

To JUDY, BRANT, and  
for their love and unders

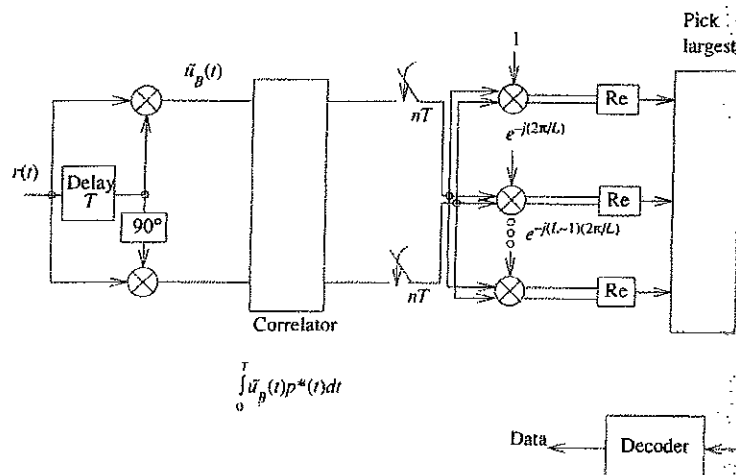
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Fig. 5.26 Receiver for  $L$ -phase differentially coherent PSK.

The probability of symbol error can be analyzed as for the differentially encoded, coherently received system of the last section, and approximated as described in [3]. The result is

$$P_e \sim 2Q \left[ (E_p/N_0)^{1/2} \sin(\pi/L) \right] = 2Q \left[ (E_b \log_2(L)/N_0)^{1/2} \sin(\pi/L) \right] \quad (5.75)$$

plotted as the solid curves in Figure 5.25.

Comparing this with (5.68), twice as much energy is (asymptotically) required in order to achieve the same  $P_e$  as CPSK. This is because two receiver noisy phase functions — and hence twice as much noise — were brought into the receiver. However, for  $L=2$  (binary) the difference at high SNR is small, making DCPSK a logical choice in some applications.

### 5.2.6 QAM AND "OPTIMAL" TWO-DIMENSIONAL SIGNAL SETS

We have so far examined single sideband and phase modulation as examples of linear two-dimensional passband communication systems. In the case of single sideband, we had real signal points  $\tilde{d}_n = a_n$  and a complex analytic pulse  $\tilde{p}(t)$ , as suggested by (5.50). For phase modulation, the data  $d_n$  were complex with equal magnitude and equally spaced on a circle in the complex plane, and  $p(t)$  was a real pulse. We now turn to another popular modulation format, quadrature amplitude modulation (QAM), and to variations on it that provide more immunity against one or another channel impairment. In this modulation format, the signal points are located on  $L = M^2$  equally spaced points in the complex

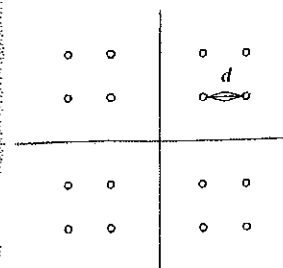


Fig. 5.27 Comparison of minimum distance constellations with the same average power.

plane (as in Figure 5.27a). For QAM valid for high SNR, we find that constellations that perform best against Gaussian noise are those that perform best against Gaussian noise.

We presume a real pulse  $p(t)$  and signal points  $s_1, \dots, s_L$ . As already noted, a signal point is often referred to as  $\tilde{d}_n = a_n + jb_n$  is selected from this set. The average power is used to compare different constellations.

### SPECTRAL EFFICIENCY VS. PERFORMANCE

Constellations with many points are more efficient than those with few points, as expressed in (5.1). A 16-point constellation has the 1 bps/Hz of a two-point constellation with average power constrained, so that as the number of points increases, increasing the probability of a signal point into the wrong decision region. For the same average power, a 16-phase constellation has a smaller minimum spacing than that of a 2-phase constellation. To determine the performance (again, in terms of error rate) of constellations such as QAM, we must compare them in the complex plane, as in Figure 5.27b. This mandates a large signal set. Figure 5.27c shows a constellation perturbed by Gaussian noise.

### A GOOD ESTIMATION TECHNIQUE FOR CONSTELLATIONS

We will compare the performance of different constellations by doing that we need a way of

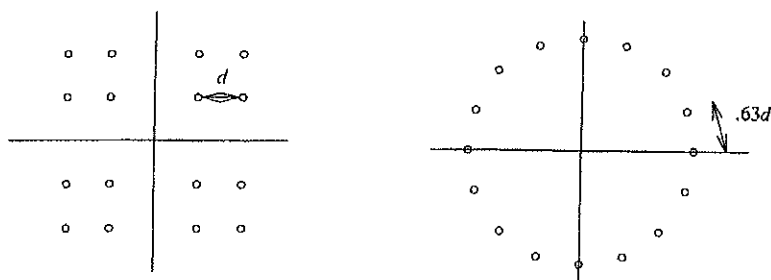


Fig. 5.27 Comparison of minimum distance between signal points in QAM and 16-phase signal constellations with the same average power  $2.5 d^2$ .

plex plane (as in Figure 5.27a). In addition to deriving an error-rate expression for QAM valid for high SNR, we will derive signal constellations of various sizes that perform best against Gaussian noise.

We presume a real pulse  $p(t)$  and begin with no restrictions on the set of  $L$  signal points  $s_1, \dots, s_L$ . As already noted in connection with PSK, the set of signal points is often referred to as a *signal constellation*. Each modulation level  $d_n = a_n + jb_n$  is selected from this set, and the transmitted signal is expressed by (5.44). The average power is usually assumed fixed, especially when comparing different constellations.

#### SPECTRAL EFFICIENCY VS. ERROR MARGIN

Constellations with many points are used for bandwidth efficiency, as expressed in (5.1). A 16-point constellation yields close to 4 bps/Hz, compared with the 1 bps/Hz of a two-point constellation, e.g. a simple on-off signal. But with average power constrained, signal points are closer together as their number increases, increasing the probability that noise or other perturbations will drive a signal point into the wrong decision region. As Figure 5.27 illustrates, for the same average power, a 16-phase constellation has signal points with a much smaller minimum spacing than that of 16-point QAM. We will see below that for the same average power, the minimum distance between signal points will determine the performance (against noise) of the constellation. That is the reason why constellations such as QAM, with signal points distributed more uniformly in the complex plane, are used when the need for high spectral efficiency mandates a large signal set. Figure 5.28 illustrates a 16-point QAM constellation perturbed by Gaussian noise and phase jitter.

#### A GOOD ESTIMATION TECHNIQUE FOR COMPARING SIGNAL CONSTELLATIONS


We will compare the performance of various constellations, but before doing that we need a way of easily determining (albeit through numerical

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where the dimension  $N$  is the number of basis functions involved in formulating the signal vector  $\mathbf{s}_i$ . The individual components of the signal vector  $\mathbf{s}_i$  and noise vector  $\mathbf{w}$  are defined by Equations (5.6) and (5.31), respectively. The theorem of irrelevance and its corollary are indeed basic to the understanding of the signal detection problem as described next.

### 5.4 Likelihood Functions

The conditional probability density functions  $f_{\mathbf{x}}(\mathbf{x}|\mathbf{m}_i)$ ,  $i = 1, 2, \dots, M$ , are the very characterization of an AWGN channel. Their derivation leads to a functional dependence on the observation vector  $\mathbf{x}$ , given the transmitted message symbol  $\mathbf{m}_i$ . However, at the receiver we have the exact opposite situation: We are given the observation vector  $\mathbf{x}$  and the requirement is to estimate the message symbol  $\mathbf{m}_i$  that is responsible for generating  $\mathbf{x}$ . To emphasize this latter viewpoint, we introduce the idea of a *likelihood function*, denoted by  $L(\mathbf{m}_i)$  and defined by

$$L(\mathbf{m}_i) = f_{\mathbf{x}}(\mathbf{x}|\mathbf{m}_i), \quad i = 1, 2, \dots, M \quad (5.49)$$

It is important however to recognize that although the  $L(\mathbf{m}_i)$  and  $f_{\mathbf{x}}(\mathbf{x}|\mathbf{m}_i)$  have exactly the same mathematical form, their individual meanings are different.

In practice, we find it more convenient to work with the *log-likelihood function*, denoted by  $l(\mathbf{m}_i)$  and defined by

$$l(\mathbf{m}_i) = \log L(\mathbf{m}_i), \quad i = 1, 2, \dots, M \quad (5.50)$$

The log-likelihood function bears a one-to-one relationship to the likelihood function for two reasons:

1. By definition, a probability density function is always nonnegative. It follows therefore that the likelihood function is likewise a nonnegative quantity.
2. The logarithmic function is a monotonically increasing function of its argument.

The use of Equation (5.46) in (5.50) yields the log-likelihood functions for an AWGN channel as

$$l(\mathbf{m}_i) = -\frac{1}{N_0} \sum_{j=1}^N (x_j - s_{ij})^2, \quad i = 1, 2, \dots, M \quad (5.51)$$

where we have ignored the constant term  $-(N/2) \log(\pi N_0)$  as it bears no relation whatsoever to the message symbol  $\mathbf{m}_i$ . Note that the  $s_{ij}$ ,  $j = 1, 2, \dots, N$ , are the elements of the signal vector  $\mathbf{s}_i$  representing the message symbol  $\mathbf{m}_i$ . With Equation (5.51) at our disposal, we are now ready to address the basic receiver design problem.

### 5.5 Coherent Detection of Signals in Noise: Maximum Likelihood Decoding

Suppose that in each time slot of duration  $T$  seconds, one of the  $M$  possible signals  $s_1(t)$ ,  $s_2(t)$ ,  $\dots$ ,  $s_M(t)$  is transmitted with equal probability,  $1/M$ . For geometric signal representation, the signal  $s_i(t)$ ,  $i = 1, 2, \dots, M$ , is applied to a bank of correlators, with a common input and supplied with an appropriate set of  $N$  orthonormal basis functions. The resulting correlator outputs define the *signal vector*  $\mathbf{s}_i$ . Since knowledge of the signal vector  $\mathbf{s}_i$  is as good as knowing the transmitted signal  $s_i(t)$  itself, and vice versa, we may represent  $s_i(t)$  by a point in a Euclidean space of dimension  $N \leq M$ . We refer to this point as the *trans-*

## 5.5 Maximum Likelihood Decoding 323

*mitted signal point* or *message point*. The set of message points corresponding to the set of transmitted signals  $\{s_i(t)\}_{i=1}^M$  is called a *signal constellation*.

However, the representation of the received signal  $x(t)$  is complicated by the presence of additive noise  $w(t)$ . We note that when the received signal  $x(t)$  is applied to the bank of  $N$  correlators, the correlator outputs define the observation vector  $\mathbf{x}$ . From Equation (5.48), the vector  $\mathbf{x}$  differs from the signal vector  $\mathbf{s}_i$  by the *noise vector*  $\mathbf{w}$  whose orientation is completely random. The noise vector  $\mathbf{w}$  is completely characterized by the noise  $w(t)$ ; the converse of this statement, however, is not true. The noise vector  $\mathbf{w}$  represents that portion of the noise  $w(t)$  that will interfere with the detection process; the remaining portion of this noise, denoted by  $w'(t)$ , is tuned out by the bank of correlators.

Now, based on the observation vector  $\mathbf{x}$ , we may represent the received signal  $x(t)$  by a point in the same Euclidean space used to represent the transmitted signal. We refer to this second point as the *received signal point*. The received signal point wanders about the message point in a completely random fashion, in the sense that it may lie anywhere inside a Gaussian-distributed "cloud" centered on the message point. This is illustrated in Figure 5.7a for the case of a three-dimensional signal space. For a particular realization of the noise vector  $\mathbf{w}$  (i.e., a particular point inside the random cloud of Figure 5.7a), the relationship between the observation vector  $\mathbf{x}$  and the signal vector  $\mathbf{s}_i$  is as illustrated in Figure 5.7b.

We are now ready to state the signal detection problem:

Given the observation vector  $\mathbf{x}$ , perform a mapping from  $\mathbf{x}$  to an estimate  $\hat{m}$  of the transmitted symbol,  $m_i$ , in a way that would minimize the probability of error in the decision-making process.

Suppose that, given the observation vector  $\mathbf{x}$ , we make the decision  $\hat{m} = m_i$ . The probability of error in this decision, which we denote by  $P_e(m_i | \mathbf{x})$ , is simply

$$\begin{aligned} P_e(m_i | \mathbf{x}) &= P(m_i \text{ not sent} | \mathbf{x}) \\ &= 1 - P(m_i \text{ sent} | \mathbf{x}) \end{aligned} \quad (5.52)$$

The decision-making criterion is to minimize the probability of error in mapping each given observation vector  $\mathbf{x}$  into a decision. On the basis of Equation (5.52), we may therefore state the *optimum decision rule*:

$$\begin{aligned} &\text{Set } \hat{m} = m_i \text{ if} \\ &P(m_i \text{ sent} | \mathbf{x}) \geq P(m_k \text{ sent} | \mathbf{x}) \quad \text{for all } k \neq i \end{aligned} \quad (5.53)$$

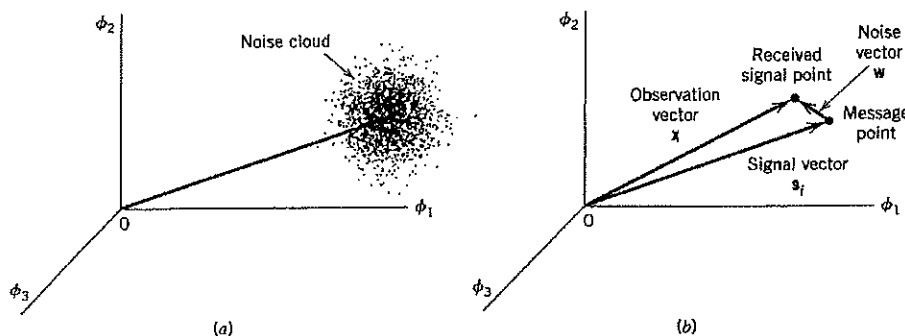


FIGURE 5.7 Illustrating the effect of noise perturbation, depicted in (a), on the location of the received signal point, depicted in (b).

# EXHIBIT E

# **DIGITAL COMMUNICATION**

**Edward A. Lee**  
*University of California at Berkeley*

**David G. Messerschmitt**  
*University of California at Berkeley*



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result from the demodulation. These phase errors are corrected by further demodulation shown as a complex multiply following the fractionally-spaced filter and sampler. The reason for doing this two-step demodulation is that the carrier recovery is decision-directed, like the timing recovery. A loop is formed that includes the carrier recovery, and a complex multiplier, as shown in figure 6-25. It becomes clear in chapter 14 that the performance of this structure is considerably better if there is no additional filtering inside the loop (the feedback equalizer is formed at this configuration). Consequently the final demodulation should be done as close to the slicer as possible. The preliminary demodulation, however, is required to reduce the signal down close to baseband so that the receiver does not have to operate on the high frequency signal. Sometimes this final demodulation can be achieved simply by sampling the signal below the Nyquist rate, without using the complex multiplier shown in figure 6-25.

Some of the possible variations on the receiver shown in figure 6-25 include the use of error correcting codes (chapter 11) or trellis codes (chapter 12), the use of Viterbi detector instead of the slicer and equalizers (section 8.7), or the omission of the feedback equalizer (chapters 8 and 9). It is also practical to design passband directly if we are not PAM signals, for example FSK (section 6.6 below) or continuous phase modulation (section 10.4), in which case the receivers are significantly different. Receiver receivers can also get more elaborate than those discussed in section 6.3 above, for example line coding (chapter 10) and adaptive equalization (chapters 8 and 9).

## 6.5. PERFORMANCE OF PAM AND ALPHABET DESIGN

For the purposes of this section, the entire system may be viewed as a discrete-time system as shown in figure 6-24. A baseband communication system is just a special case where the symbols  $A_k$ , baseband equivalent channel  $p_k$ , and the noise  $Z_k$  are real-valued. The problem we consider in this section is the design of an alphabet and a slicer, and the impact of these designs on the probability of error.

### 6.5.1. Constellations

The alphabet is the set of symbols that are available for transmission. The receiver uses a slicer which makes the decision about the intended symbol. The input to the slicer is a discrete-time signal with sample interval equal to the symbol rate. When there is no intersymbol interference (ISI), then each sample into the slicer is equal to the transmitted data symbol corrupted by an additive noise that is independent of the symbol sequence. For the receivers considered so far, the noise component of the slicer input sample is Gaussian when the channel noise  $N(t)$  is Gaussian. In the case of the passband receivers, the transmitted symbol is complex-valued and the additive noise sample is complex-valued with jointly Gaussian real and imaginary parts. Hence, in all cases the function of the slicer is to detect the transmitted symbol in the presence of additive Gaussian noise.

A baseband signal has a real-valued alphabet that is simply a list of real numbers, for example  $A = \{-3, -1, 1, 3\}$ . A passband PAM signal has an alphabet that is a list of complex numbers, for example  $A = \{-1, j, +1, -j\}$ . Both of these example alphabets

have size  $M = 4$ ; each symbol is best described by such a plot is called a constellation diagram. The points in the plot are the symbols and are illustrated in figure 6-26.

#### Example 6-27.

The 4-PSK constellation is shown in figure 6-26, each with a different phase.

and the transmitted signal is

where  $\phi_k$  assumes the phase of the phase shift keying signal (PSK). [1]

#### Example 6-28.

The 16-QAM constellation is shown in figure 6-27. Because the system is a passband

in a baseband PAM signal, the 16-QAM signal is a special case of the PAM signal. Because of additive Gaussian noise

Figure 6-26  
4-PSK constellation

have size  $M = 4$ ; each symbol can represent  $\log_2 M = 2$  bits. A complex-valued alphabet is best described by plotting the alphabet as a set of points in a complex plane. Such a plot is called a *signal constellation*. There is a one-to-one correspondence between the points in the constellation and the signal alphabet. Two popular constellations are illustrated in the following examples.

**Example 6-27.**

The 4-PSK constellation is shown in figure 6-26a. It consists of four symbols of magnitude  $b$ , each with a different phase. Hence the symbols may be written

$$A_m = be^{j\phi_m} \quad (6.88)$$

and the transmitted signal may be written (from (6.57))

$$X(t) = b\sqrt{2} \sum_{m=-\infty}^{\infty} \cos(\omega_c t + \phi_m) g(t - mT) \quad (6.89)$$

where  $\phi_m$  assumes the four values from the set  $\{0, \pi/2, \pi, 3\pi/2\}$ . The information is carried on the phase of the carrier, and the amplitude of the carrier is constant, and hence the term *phase-shift keying* (PSK). The 4-PSK constellation is also called *quadrature phase-shift keying* (QPSK).  $\square$

**Example 6-28.**

The 16-QAM constellation shown in figure 6-26b has 12 possible phases and three amplitudes. Because of the rectangular nature of the constellation, the rectangular coordinate system is preferable to the polar coordinates that are natural in four phase PSK.  $\square$

In a baseband PAM system, the real-valued alphabet can also be plotted as a one-dimensional constellation, although this is perhaps less informative. Since baseband PAM is a special case of passband PAM, we will concentrate on passband PAM for the remainder of this chapter.

Because of additive noise, the received samples at the input to the slicer will not correspond exactly to points in the signal constellation, but if the noise power is small

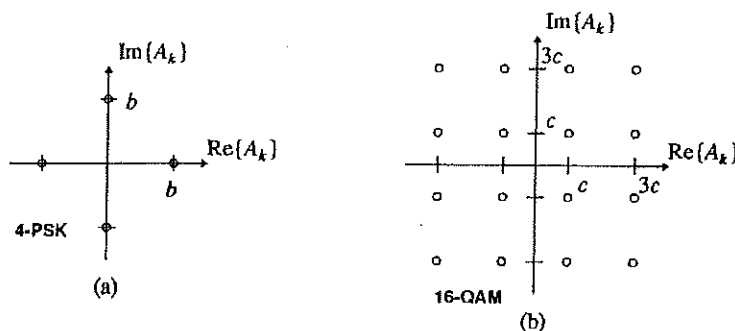


Figure 6-26. Two popular constellations for passband PAM transmission. The constants  $b$  and  $c$  affect the power of the transmitted signal.